TABLE OF CONTENTS

1. INTRODUCTION 1-1
   1.1. Applications 1-1
   1.2. Specifications 1-1
   1.3. Conventions used in this manual 1-2
   1.4. How to use this manual 1-2

2. PORTABLE TILT METER 2-1
   2.1. General description 2-1
       2.1.1. Tilt plate 2-1
       2.1.2. Tilt meter 2-1
       2.1.3. Readout unit 2-2
   2.2. Taking readings 2-2
       2.2.1. Reading horizontal tilt plates 2-2
       2.2.2. Reading vertical tilt plates 2-3
       2.2.3. Taking readings with TRITECH model TES-DI-53 UTM readout unit 2-4
   2.3. Sample test certificate 2-6

3. INSTALLATION PROCEDURE 3-1
   3.1. Orientation of horizontal tilt plates 3-1
   3.2. Orientation of vertical tilt plates 3-1
   3.3. Mounting procedure of tilt plates 3-1
       3.3.1. Anchors and screws 3-1
       3.3.2. Using grout 3-1
   3.4. Tools & accessories required for installation 3-2

4. DATA REDUCTION 1
   4.1. Displayed readings 1
   4.2. Combining + and – readings 1
   4.3. Calculating tilt 1
1. Introduction

TRITECH model TES-AN-70M portable high resolution uniaxial tilt meter is suitable for monitoring inclination and vertical rotation in structures. It is rugged in construction and has excellent temperature stability.

Tilt changes in a structure may be caused by construction activity such as excavation, tunneling or de-watering that may affect ground that supports the structure. Change in tilt may also result from loading of a structure, such as loading of a dam during impoundment, loading of a diaphragm wall during excavation or loading of a bridge deck due to wind and traffic. Data from tilt meter provides early warning of threatening deformation, allowing time for corrective action to be taken or if necessary, for safe evacuation of the area.

TES-AN-70M tilt measurement system consists of two components – a portable tilt meter and a number of bronze tilt plates. Individual tilt plates are fixed with either epoxy or screws at designated locations on a structure where tilt is to be monitored. To get tilt readings the user has to place the portable tilt meter on the mounted tilt plate to get tilt reading at that location. The portable tilt meter has to be carried from one tilt plate to another to get readings at different locations. Although TES-AN-70M is a uniaxial tilt meter it can be used to take biaxial measurements at any particular location by rotating the tiltmeter by 90° on the tilt plate and taking a second reading.

TES-AN-70M tilt meter is not suitable for use with automatic data acquisition systems. TRITECH offers a different tilt meter model EAN-90M for use with data acquisition systems.

1.1. Applications

TES-AN-70M can be used for measurement of tilt of a structure along any vertical plane or along two orthogonal vertical planes. Following are some examples of its use:

- Monitoring critical structures in zone of influence of cut and cover excavation/tunnelling activity.
- Monitoring vertical rotation of retaining walls.
- Monitoring inclination of dams, piers and piles etc.
- Monitoring stability of structures in landslide areas.
- Monitoring performance of bridges.

1.2. Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of axes</td>
<td>Uniaxial (biaxial measurement is possible by rotating tilt meter by 90° on tilt plate in a horizontal plane)</td>
</tr>
<tr>
<td>Standard range</td>
<td>± 15° from vertical</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>± 10 arc second</td>
</tr>
<tr>
<td>Accuracy</td>
<td>± 0.1 % fs</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>± 9 V to ± 12V dc</td>
</tr>
<tr>
<td>Supply current</td>
<td>Less than 35 mA from each supply</td>
</tr>
<tr>
<td>Temperature range</td>
<td>-20°C to 50°C</td>
</tr>
<tr>
<td>Temperature coefficient</td>
<td>0.005 %/°C</td>
</tr>
<tr>
<td>Dimensions</td>
<td>162L x 90B x 145H mm</td>
</tr>
<tr>
<td>Material</td>
<td>Stainless steel frame, anodised aluminium housing</td>
</tr>
<tr>
<td>Weight</td>
<td>3.6 kg (sensor)</td>
</tr>
<tr>
<td>Output connection</td>
<td>Integral six pin circular connector</td>
</tr>
</tbody>
</table>

1 As tested under laboratory conditions
1.3. Conventions used in this manual

**WARNING!** Warning messages calls attention to a procedure or practice that if not properly followed could possibly cause personal injury.

**CAUTION:** Caution messages calls attention to a procedure or practice that if not properly followed may result in loss of data or damage to equipment.

**NOTE:** Note contains important information and is set off from regular text to draw the users’ attention.

1.4. How to use this manual

The users’ manual is intended to provide sufficient information for making optimum use of portable tilt meter in different applications.

To make the manual more useful we invite valuable comments and suggestions regarding any additions or enhancements. We also request to please let us know of any errors that are found while going through the manual.

**NOTE:** Installation personnel must have a background of good installation practices and knowledge of fundamentals of geotechnics. Novices may find it very difficult to carry on installation work. The intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has been made in preparing this instruction manual. However best of instruction manuals cannot provide for each and every condition in field that may affect performance of the sensor. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, installation personnel will have to consciously depart from written text and use their knowledge and common sense to find solution to a particular problem.

Installation and measurements using portable tilt meter requires expertise. It is recommended that potential users themselves practice all operations laid down in this manual by repeated installations.
2. **Portable tilt meter**

2.1. **General description**

Model TES-AN-70M tilt meter is built around a precision accelerometer and suitable signal conditioning circuit mounted inside an anodized aluminium housing. The accelerometer senses force of acceleration due to gravity which is maximum when accelerometer is rotated to full 90° tilt position and is zero (minimum) when the tilt angle of the accelerometer is 0°. For in-between angles of tilt, force experienced by accelerometer is equal to product of sine of tilt angle and acceleration due to gravity. Tilt sensor provides a bipolar DC voltage output proportional to sine of tilt angle measured by the tilt meter. Output is zero volts for a truly vertical sensor.

The sensor provides a relatively low cost tilt measurement solution with excellent resolution, long term stability and low thermal sensitivity.

The tilt meter can be used to measure change in tilt of any vertical surface or horizontal floor by placing it on a suitable reference tilt plate, available separately.

The TES-AN-70M is not intended for absolute determination of tilt of structures. It measures change in tilt of structures to which reference tilt plate is attached. Initial tilt reading for each tilt plate is recorded after it is mounted on structure to be monitored. Subtracting initial tilt reading from subsequent tilt readings give change in tilt of structure over a period of time.

2.1.1. **Tilt plate**

Tilt plate is a bronze disc about 125 mm in diameter. It is fixed to the structure with epoxy, grout or anchors. The four pegs on the tilt plate are used to orient the tilt meter.

Horizontally mounted tilt plate allows tilt readings in two planes that are at 90° to each other. Vertically mounted tilt plate allows tilt readings along one vertical plane only.

2.1.2. **Tilt meter**

Portable tilt meter is carried from one tilt plate to another to obtain tilt readings. Alignment bars have been provided on bottom, front and rear side of tilt meter. These are used to accurately position tilt meter on tilt plate.

Two readings are taken for each tilt plane - one reading in plus direction and another in minus direction. The base plate of tilt meter has + and - marks to assist proper orientation of the tilt meter.
2.1.3. **Readout unit**

TRITECH digital readout unit model TES-DI-53UTM is used to take observations from portable tilt meter. It displays readings in terms of Sin (tilt angle). The sign of reading is (+ or -) according to direction of tilt.

2.2. **Taking readings**

Allow time for tilt meter to adjust to ambient temperature. If possible, store tilt meter at same temperature as at time of taking readings. Connect tilt meter to readout and power up. Take readings as follows:

2.2.1. **Reading horizontal tilt plates**

- Take reading in plane “A” first. In figures 4 below, pegs 1 and 3 define direction of plane “A”. Place “+” end of tilt meter on peg 1, wait for reading to stabilize, and record it. Rotate tilt meter 180° and place “-” end of tilt meter on peg 1, wait for reading to stabilize and record it.

- Repeat steps two to three times to ensure readings are repeatable. In theory A+ and A - readings should be identical except for different sign (+/-). In practice there is a difference up to 0.003 on TRITECH readout unit TES-DI-53UTM between two readings due to bias of sensor and small irregularities in tilt plate.

- Figure 4 below shows positioning of portable tilt meter on tilt plate for taking readings in plane A.
Take readings in plane B next. Plane B is defined by direction of pegs 2 and 4. Place “+” end of tilt meter on peg 4, wait for reading to stabilize and record it. Rotate tilt meter 180° and place “-” end of tilt meter on peg 4, wait for reading to stabilize and record it. Figure 4 & 5 explain positioning of portable tilt meter on tilt plate to take readings in plane A and B respectively.

Repeat steps two to three times to ensure readings are repeatable. In theory B+ and B - readings should be identical except for different sign (+/−). In practice there is a difference up to 0.003 on TRITECH readout unit TES-DI-53UTM between two readings due to bias of sensor and small irregularities in tilt plate.

Figure 5 below shows positioning of portable tilt meter on tilt plate for taking readings in plane B.

2.2.2. Reading vertical tilt plates

Vertical tilt plate allows reading in tilt plane A defined by direction of pegs 1 and 3. The tilt meter is aligned using alignment bars at ends of tilt meter.

Place “+” end of tilt meter against peg 1, wait for reading to stabilize and record it. Refer to figure 6.

Place “-” end tilt meter against peg 1, wait for readings to stabilize and record it.

Repeat these steps three times to ensure that you have good repeatable readings.

Repeat steps two to three times to ensure readings are repeatable. In theory readings should be identical except for different sign (+/−). In practice there is a difference up to 0.003 on TRITECH readout unit TES-DI-53UTM between two readings due to bias of sensor and small irregularities in tilt plate.

Figure 6 below shows position of portable tilt meter on tilt plate for taking readings in vertical plane B.
2.2.3. Taking readings with TRITECH model TES-DI-53 UTM readout unit


TRITECH model TES-DI-53 UTM portable readout unit is a microprocessor based indicator that reads sine of tilt angle when parameters of a typical portable tilt meter are fed.

The TES-DI-53 indicator can store initial data from up to 250 tilt plates so that change in tilt angle measured from these tilt plates can be determined in proper engineering units.

The indicator has an internal non-volatile memory with sufficient capacity to store about 3600 readings from any of the 250 programmed tilt plates in any combination. You can store either 3600 readings from any one tilt plate or 14 sets of readings from all 250 tilt plates. Each reading is stamped with the date and time the measurement was taken.

The stored readings can either be uploaded to a host computer using the serial interface or can be printed out on any text printer equipped with a RS-232C serial communications interface. The setup information (calibration coefficients) for all the channels can also be printed out for verification.

Setting up the TES-DI-53 UTM indicator is easy as all the prompts and error messages are in plain simple English language. Power on self tests and a separate test mode operation for more detailed diagnostics are an added advantage.

An internal 6V rechargeable sealed maintenance free battery is used to provide power to the indicator. A fully charged new battery provides nearly 60 hours of operation on a single charge. A separate battery charger is provided with the TES-DI-53 UTM indicator to charge the internal battery from 230 V AC mains.

![Figure 6 taking readings in vertical plane](image-url)
The TES-DI-53 UTM indicator is housed in a splash proof plastic moulded enclosure with weather proof connectors for making connections to the transducer and the battery charger.

To read sine of tilt angle one has to setup TES-DI-53UTM channel as follows:

- **Units [UNITS]**: No units (key 9)
- **Initial reading [IR]**: Set to zero
- **Gauge factor [GF]**: 2/portable tilt meter gage factor in volts/sin 90
- **Coeff. Of X²**: Set to zero
- **Decimal point [DP]**: as required
2.3. Sample test certificate

![TriTech Logo]

**TRITECH INSTRUMENTS PTE LTD**

2 Kaki Bukit, Place TriTech Building #06-00 Singapore 416180
Tel: 68482567  Fax: 68482568  Email: instruments@tritech.com.sg

---

**TEST CERTIFICATE**

| Customer : | Date       : 18.05.2007 |
| P.O.       : | Temperature : 33 ºC |
| Item       : Portable tilt meter (Uniaxial) |
| Model      : TES-AN-70M |
| Range      : ±15º |
| Serial no. : 0705002 |

**Test data**

<table>
<thead>
<tr>
<th>Test position arc degrees</th>
<th>Sin(A)</th>
<th>*Calculated output (+A axis)</th>
<th>Observed output (-A axis)</th>
<th>Average</th>
<th>Best fit Sin(A)</th>
<th>Error</th>
<th>Non-conformance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A)</td>
<td>(X)</td>
<td>(V1)</td>
<td>(V2)</td>
<td>(V3)</td>
<td>(V4)</td>
<td>(Y)</td>
<td>(X~Y)</td>
</tr>
<tr>
<td>Volts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.01746</td>
<td>0.2794</td>
<td>0.277</td>
<td>-0.281</td>
<td>0.279</td>
<td>0.01743</td>
<td>0.00003</td>
</tr>
<tr>
<td>2</td>
<td>0.03491</td>
<td>0.5586</td>
<td>0.555</td>
<td>-0.559</td>
<td>0.557</td>
<td>0.03491</td>
<td>0.00001</td>
</tr>
<tr>
<td>3</td>
<td>0.05236</td>
<td>0.8377</td>
<td>0.833</td>
<td>-0.837</td>
<td>0.835</td>
<td>0.05239</td>
<td>0.00003</td>
</tr>
<tr>
<td>6</td>
<td>0.10457</td>
<td>1.6731</td>
<td>1.664</td>
<td>-1.667</td>
<td>1.666</td>
<td>0.10460</td>
<td>0.00003</td>
</tr>
<tr>
<td>9</td>
<td>0.15650</td>
<td>2.5040</td>
<td>2.49</td>
<td>-2.491</td>
<td>2.491</td>
<td>0.15647</td>
<td>0.00003</td>
</tr>
<tr>
<td>12</td>
<td>0.20799</td>
<td>3.3279</td>
<td>3.309</td>
<td>-3.311</td>
<td>3.310</td>
<td>0.20799</td>
<td>0.00000</td>
</tr>
<tr>
<td>15</td>
<td>0.25892</td>
<td>4.1427</td>
<td>4.118</td>
<td>-4.122</td>
<td>4.120</td>
<td>0.25892</td>
<td>0.00000</td>
</tr>
</tbody>
</table>

Max non-conformance (% fs) : 0.012

Sensor gauge factor (G) : 6.287E-02 Sin(90)/Volts

[Sensor gage factor for read out unit Model : TES-DI-53 UTM is 15.905 Volts/Sin (90)**]

Regression zero (R0) : 1.770E-03

Calculation of tilt value (arc degree)

\[ \text{SinA} = G \times (R1 - R0) \]

\[ A = \text{Sin}^{-1}[G^*(R1 - R0)] \]

\[ R1 = \text{Current display reading in volts} \]

\[ R0 = \text{Regression zero} \]

\[ G = \text{Gage factor} \]

Wiring code :

<table>
<thead>
<tr>
<th>Pin ID</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+ 12 V (supply )</td>
</tr>
<tr>
<td>B</td>
<td>- 12 V (supply )</td>
</tr>
<tr>
<td>C</td>
<td>0 V (supply )</td>
</tr>
<tr>
<td>D</td>
<td>Output 'A' axis</td>
</tr>
<tr>
<td>E</td>
<td>Output 'B' axis NA</td>
</tr>
<tr>
<td>F</td>
<td>Output common</td>
</tr>
</tbody>
</table>

Note :

*Calculated output Voltage (V1) worked out based on nominal gauge factor of 16.000 V/g (i.e. 16V X Sin A ).

Calculation of GF shall be done as per notes given in test certificate of read out unit TES-DI-53 UTM **.

Checked by       Tested by

---

2-6
3. Installation procedure

Tilt plates are placed on structural members that are representative of the large structure. When a single location does not represent the structure, additional tilt plates are placed at other locations.

Number of tilt plates needed is determined by stiffness of the structure and accuracy desired. Stiffer structures require fewer plates. To achieve high accuracy, more plates are required. Tilt plates are generally placed with one set of pegs oriented to the expected direction of rotation. Location of tilt plate shall be chosen such they are easily accessible.

Be careful to avoid installation of tilt plates on expensive exteriors like marble, granite, tiles or special materials where cost of make good would be very high.

3.1. Orientation of horizontal tilt plates

Horizontal plates provide two planes of measurement. Plane A is defined by pegs 1 & 3. Peg 1 is usually oriented towards the direction of tilt. Plane B is defined by pegs 2 & 4. Peg 4 is usually oriented toward the direction of tilt.

3.2. Orientation of vertical tilt plates

Vertical tilt plates should be aligned so that a vertical line can be drawn through pegs 1 and 3.

3.3. Mounting procedure of tilt plates

Tilt plates can be fixed to the structure with anchors and screws or with grout. When tilt plate experiences temperature changes or weather, a combination of both anchors and grout works best.

3.3.1. Anchors and screws

- Prepare a clean flat surface.
- Place tilt plate on structure in its intended orientation. Mark location of anchors.
- Drill holes large enough and deep enough to accommodate anchors.
- Screw tilt plate to anchors.
- Check and ensure correctness of horizontal and vertical position of tilt plate by using a spirit level.

3.3.2. Using grout

- Prepare a clean, flat surface.
- Place a pad of grout thick enough so that the tilt plate can be pressed into it and levelled.
- Orient tilt plate correctly and press it into grout. Allow grout to enter the screw holes and overlap edges of the plate. Check that grout is not left out on any of the pegs.
3.4. Tools & accessories required for installation

- Hilti Impact fastener polyamide no. HPS 1-6/15X40 or equivalent
- Star head screw driver
- Sprit level 150mm Drill bit 6mm
- Power drill machine
- Ball point hammer, 250 gm.
4. **Data reduction**

One is generally interested in finding change in tilt of a structure. To find change in tilt, subtract initial tilt from current tilt and convert result in degrees or displacement.

4.1. **Displayed readings**

TRITECH readout unit model TES-DI-53UTM display the readings in terms of sin (tilt angle).

\[ \text{Displayed readings} = \sin(A) \]

where \( A \) = angle of tilt

4.2. **Combining + and – readings**

Obtain two readings for each tilt plane, a “+” reading a “-“ reading. In the data reduction process, add the two readings to eliminate sensor bias. Denote this value by “DIFF” (algebraic difference). A positive DIFF value indicate tilt toward + end of tilt meter.

\[ \text{DIFF} = (+ \text{ reading}) - (- \text{ reading}) \]

4.3. **Calculating tilt**

To convert the DIFF value to tilt in degrees, divide it by 2 because the DIFF value comprises of two readings. Take inverse sine of this value to get angle of tilt in degrees.

\[ \text{Angle of tilt} = \sin^{-1} \left( \frac{\text{DIFF}}{2} \right) \]

To calculate change in tilt use following formula:

\[ \text{Change in tilt} = \sin^{-1} \left( \frac{\text{DIFF}_2}{2} \right) - \sin^{-1} \left( \frac{\text{DIFF}_1}{2} \right) \]

- where DIFF\(_1\) is the initial reading (tilt reading taken just after installation) and DIFF\(_2\) is the current tilt reading (reading taken on a subsequent date)
- Drill bit 6mm
- Power drill machine
- Ball point hammer, 250 gm.

\[ \text{Angle of tilt} = \sin^{-1} \left( \frac{\text{DIFF}}{2} \right) \]

To calculate change in tilt use following formula:

\[ \text{Change in tilt} = \sin^{-1} \left( \frac{\text{DIFF}_2}{2} \right) - \sin^{-1} \left( \frac{\text{DIFF}_1}{2} \right) \]

where DIFF\(_1\) is the initial reading (tilt reading taken just after installation) and DIFF\(_2\) is the current tilt reading (reading taken on a subsequent date).